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AUTHOR Espy, John
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ABSTRACT

This ninth in a series of ten modules for a course titled Welding Inspection describes the purposes, essential elements, and application of a weld control program. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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NUCLEAR TECHNOLOGY

COURSE 28 WELDING INSPECTION

MODULE 28-9 Weld Repair Control

CE 024 269

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 28 WELDING INSPECTION

Module 28-1 Welding Fundamentals and Processes

Module 28-2 Shielded Metal Arc and Oxyacetylene Welding

Module 28-3 Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding

Module 28-4 Weld Joint Verification

Module 28-5 Qualifications

Module 28-6 Process Controls

Module 28-7 Acceptance Inspection

Module 28-8 Filler Metal Control

Module 28-9 Weld Repair Control

Module 28-10 Records

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This module was prepared for General Physics Corporation by John Espy, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

Considerable effort is given toward producing defect-free welds. Welding processes, procedures, and personnel are qualified and detailed instructions are prepared to guide the welder in making welds. Nonetheless, weld defects occur. When they occur, acceptable repair is assured by controls implemented by weld repair procedures and instructions.

This module describes the purposes, essential elements, and application of a weld repair control program. During study of this module, one should keep in mind that the controls described are supported by the original welding program. For example, the qualifications described by Module 28-5, the acceptance inspections described by Module 28-7, and the filler material control program described by Module 28-8 directly support the weld repair control program. Such support is assumed by this module and redundant explanations are not included.

Reports of defective welds are reviewed by the engineering department who develop or designate the weld repair procedures to be used. The Nuclear QA/QC Technician primarily monitors weld repair activities to ensure compliance with specified requirements. In this regard, the QA/QC Technician typically has responsibilities to monitor for compliance with procedures for (1) tagging defective welds, (2) removal of weld defects, (3) repair of weld defects, (4) acceptance inspection of repairs, (5) use of qualified repair procedures (6) use of qualified welders and (7) use of qualified inspection personnel.

MODULE PREREQUISITES

The student/trainee should have prior training or experience in welding qualifications and acceptance inspections of welds. Completion of the previous modules in this course are required.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. State four purposes of the weld repair control program.
2. Name five essential elements of a weld repair program and describe the role of each.
3. Describe the circumstances which permit removal of non-conforming status indication from a weld.
4. Describe how UT or RT may be employed for defect location.
5. State one advantage and one disadvantage for each of machining, grinding, and thermal gouging methods of removing weld defects.
6. State two reasons why the SMA welding process is so frequently used for repair welding.
7. Name five items which are included in engineering instructions for removing a weld defect.

PURPOSES OF WELD REPAIR CONTROL

Basic Concepts

Completed welds are inspected to determine their acceptability by visual inspection and nondestructive examination. Acceptance standards are employed with each acceptance inspection method to determine if indications revealed by the inspection are acceptable. Only those indications which exceed the acceptance standards make the weld unacceptable. Therefore, an unacceptable weld is made acceptable by removing and repairing only enough indications such that the remaining indications, if any, meet the acceptance standards. Application of this concept avoids unnecessary repair and associated costs.

One can imagine the exasperation which results from repairing a weld only to find upon reexamination that the original defect is still there. That is, the portion repaired was close to, but not exactly, that position containing the defect. In welds several inches thick which contain defects somewhere within the weld volume, it is not particularly easy to accurately locate the defect. Also, when the defect is located, complete removal of the defect is necessary.

Even with successful removal of unacceptable defects, welding of the resultant cavity can introduce new defects. Such new defects can be in the repair weld metal, or it can be "damage" to adjacent areas caused by the repair process. Or, if repair welding does not introduce new defects, one must consider the effect of repair welding on the chemical and mechanical properties of the weld. In other words, are chemistry, strength, and ductility of the repair weld acceptable?

Finally, an inevitable question which arises is "how is it known that each unacceptable weld has been repaired such that all welds are now acceptable?". Construction and manufacturing activity may employ a hundred or more welders who complete tens of welds per day. When welds are found to be defective, a positive means is necessary for assuring that each defective weld is repaired.

Purposes of Weld Repair Control

From the foregoing discussion, four purposes of the weld repair program are evident. These purposes are to; (1) positively identify and accurately locate each unacceptable weld defect, (2) ensure removal of unacceptable indications prior to commencing repair welding, (3) ensure use of a qualified repair welding procedure by qualified personnel, and (4) ensure acceptance inspection of the repair weld.

ESSENTIAL ELEMENTS OF WELD REPAIR CONTROL

Five Essential Elements

A company develops written policies and procedures which assign responsibilities and duties for performing weld repair. To meet the purposes of a weld repair program, the policies and procedures cover five essential elements:

- Indication of nonconforming status of welds.
- Location and removal of defects.
- Selection and qualification of repair welding processes and personnel.
- Application of heat treatments.
- Application of acceptance inspection.

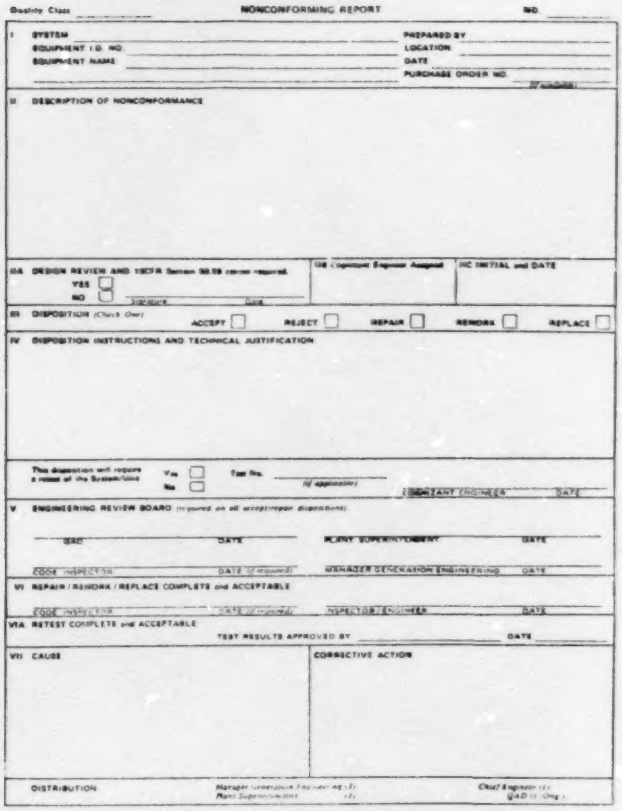
Indication of Nonconforming Status of Welds

Inspection reports are initiated whenever acceptance inspections of welds are performed. These reports identify the weld as accepted or as nonconforming dependent on the results of the inspection. When acceptance inspection determines that a weld contains defects and is, therefore, nonconforming, the inspector initiates a "nonconforming report" which describes the extent of nonconformance. This report, which is illustrated in Figure 28-9-1, is sent to engineering who determines the actions to be taken to repair or scrap the item. While actions are underway or the nonconforming report, physical identification on the weld is necessary to avoid the inadvertant use of the nonconforming weld. In other words, memory of shop personnel that the weld is nonconforming is not relied upon. Instead, a tag or label is placed on the components.

Tags or labels placed on components to indicate existence of a nonconforming condition provide for positive identification of the status of the component. As long as the tag or label is in place, it is readily apparent that the component contains a nonconforming condition. The tag or label, such as that illustrated in Figure 28-9-2, remains on the component until completion of acceptance inspection of the weld repair. When the inspection accepts the weld repair, the inspector issues an "accept" report and removes and destroys the "reject" tag or label.

Location and Removal of Defects

Nondestructive examination inspectors are normally responsible for accurately locating each defect. Surface defects are easily located. Their location is marked on the weld by the inspector, using an acceptable marking material such as no-lead paint or halogen-free ink. Subsurface defects are more difficult to locate, especially



Quality Class _____ NONCONFORMING REPORT NO. _____

I SYSTEM _____ PREPARED BY _____
EQUIPMENT I.D. NO. _____ LOCATION _____
EQUIPMENT NAME _____ DATE _____
PURCHASE ORDER NO. _____
(If applicable)

II DESCRIPTION OF NONCONFORMANCE

IIA DESIGN REVIEW AND 10CFR Section 50.59 review required. YES ☐ NO ☐ Signature Date | IIB Cognizant Engineer Assigned | IIC INITIAL and DATE

III DISPOSITION (Check One) ACCEPT ☐ REJECT ☐ REPAIR ☐ REWORK ☐ REPLACE ☐

IV DISPOSITION INSTRUCTIONS AND TECHNICAL JUSTIFICATION

This disposition will require a revision of the Specification Yes ☐ No ☐ Tag No. _____ (If applicable)
CONSULTANT ENGINEER DATE

V ENGINEERING REVIEW BOARD (required on all accept/repair dispositions)
QAC DATE PLANT SUPERINTENDENT DATE
CODE INSPECTOR DATE (if required) MANAGER DESIGN ENGINEERING DATE

VI REPAIR / REWORK / REPLACE COMPLETE and ACCEPTABLE
CODE INSPECTOR DATE (if required) INSPECTOR/ENGINEER DATE

VIA RETEST COMPLETE and ACCEPTABLE
TEST RESULTS APPROVED BY _____ DATE _____

VII CAUSE | CORRECTIVE ACTION

DISTRIBUTION Manager (originating Department) (1) Chief Engineer (1)
Plant Superintendent (1) QAD (1 Orig.)

Figure 28-9-1

as the thickness of the weld increases. The difficulty lies with determining the depth of weld metal at which the defect exists.

The value of time spent in locating the depth of subsurface defects is proportional to time savings in removing the defect. For relatively thin weld joints, less time is required to totally remove the weld metal in an area large enough to positively encompass the defect than the time which would be required to accurately locate the depth of the defect. However, for thicker weld joints, accurately locating the depth of the defect can save time by limiting the volume of weld metal to be removed.

Either ultrasonic examination or radiographic triangu-

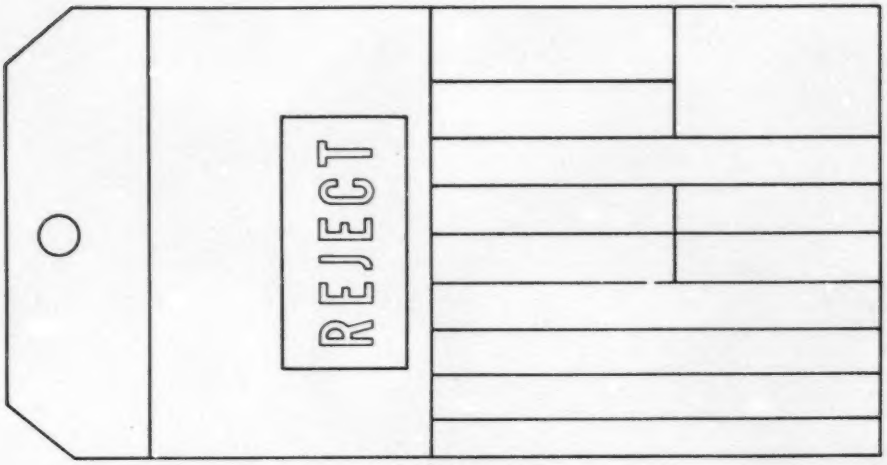
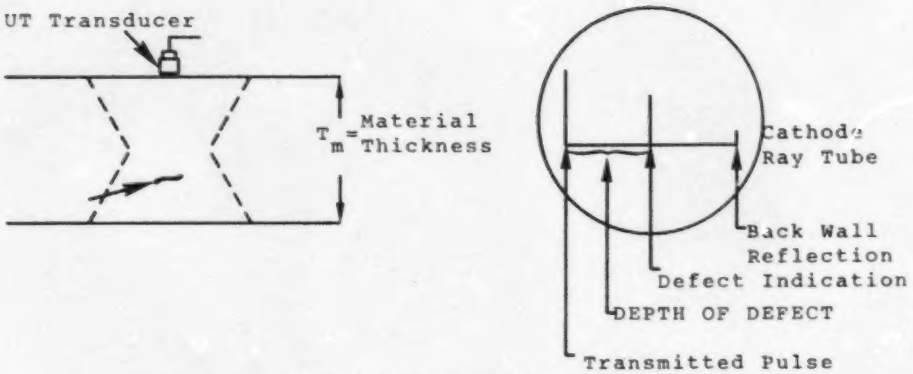


Figure 28-9-2. Sample Reject Tag

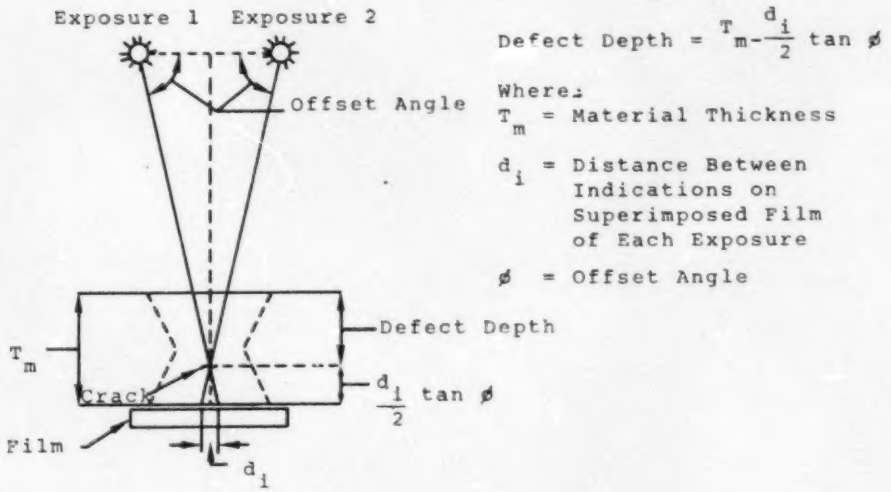
lation can accurately locate the depth of weld defects. Ultrasonic examination (UT) is the quickest of the two methods. It is used for defect depth location provided surface roughness and weld joint geometry permit application of UT. Where excess roughness or geometric forms prohibit UT, radiographic triangulation is employed. Both of these methods are illustrated in Figure 28-9-3.

In addition to marking the surface of a weld to indicate location of weld defects, the inspector prepares a sketch of the weld joint and indicates on the sketch the location and depth of the defect. This sketch serves two purposes. It assists the engineer in determining method of defect removal and it serves as a historical record of defect location.

Instructions are prepared by engineering which govern defect removal. These instructions describe the method of defect removal, the required inspection of the cavity to confirm total removal, and the required contour of the



(a) Defect Depth Location by Ultrasonic Examination



(b) Defect Depth Location by Radiographic Triangulation

Figure 28-9-3
Location of Defect Depth by UT and RT

cavity to confirm total removal, and the required contour of the cavity to permit repair welding. Typical methods for removing weld defects include machining, grinding, and thermal gouging.

- Machining - This method is relatively expensive and is typically used where a large volume of weld must be removed and thermal gouging is impractical. There is little likelihood of introducing new "damage" with this method.
- Grinding - This method is relatively inexpensive for removal of small to moderate volumes of weld metal. In general, grinding has a low probability of introducing new "damage". Conditions of concern for introducing damage include specialized surfaces, recesses and cavities. Some surfaces, such as seal membranes, must not be ground and cannot be weld repaired. If grinding must be performed next to these surfaces, it is best to place a barrier over the surface prior to grinding. Grinding dust which enters recesses and cavities presents a cleanliness problem and, for exposed electrical components, also presents a functional problem. Such areas are plugged or masked to prevent the entry of grinding dust.
- Thermal Gouging - This method employs flame or arc cutting. It is least expensive but has a higher risk of introducing new "damage". For thinner materials, its probability of burnthrough prohibits its use. Any time it is used, direction of the gouge and spatter of metal are sources of damage to surrounding materials. Also, its use is prohibited by welding codes for some materials. Finally, the resultant surface of the gouge may be too rough to permit inspection and some grinding may be necessary. This

method is used for removal of large volumes of metal where conditions can be controlled such that the stated concerns do not materialize. Otherwise, grinding or machining is employed.

The instructions for defect removal also include instructions for examining the repair cavity to determine if the defect has been removed. Either magnetic particle or liquid penetrant examination is performed. For very thick joints and for long cracks, close cooperation between the production and the quality control inspector can ensure defect removal with minimum metal removal. When production has removed sufficient metal to expose the defect, an inspector examines the surface to positively locate the defect. Successively, metal is removed and the surface is examined until the defect no longer exists. In any event, when production has completed removal of metal, the inspector examines the surfaces of the resulting cavity to ensure removal of the defect.

Finally, the instructions for defect removal describe the desired contour of the resultant cavity. Since the contour constitutes the weld joint preparation for repair welding, its shape can hinder or aid repair welding. In general the contour is required to have a bottom radius at least equal to the diameter of the filler material to be used by repair welding, blended side walls, and essentially a V or U shaped opening of sufficient width to afford welding access to the bottom of the cavity.

In summary, defect location and removal is accomplished by instructions prepared by engineering which delineate (1) location of defect, (2) method of removal of the defect, (3) precautions to be taken such as masking nearby recesses, (4) required inspection of the cavity surface, and (5) desired contour of the cavity.

Selection and Qualification of Repair Welding Procedures and Personnel

The repair welding procedure, the welder, and the NDE inspector are qualified to ensure the repair process is capable of producing a sound weld. Existing NDE personnel qualifications are valid for examination of repair welds. In general, the welding procedure and welder qualification for the original weld are also valid for the repair weld. However, each weld repair must be evaluated on its own merits to determine if existing welder and welding procedure qualifications are valid. This is because the essential variables associated with repair welding can be unavoidably different from the original welding procedure. If essential variables differ beyond limits, requalification of the welding procedure or welder or both is required. Most likely candidates for different essential variables are (1) use of SMA process for repair welding where TIG, MIG, or SAW was used for the original weld, (2) use of a welding position in repair welding not covered by the original qualification, and (3) change from flux-cored electrode to bare electrode or vice-versa when MIG is used for repairs.

Of the above candidates, the one most often encountered is use of SMA welding process for repair welding, regardless of the welding process used to initially make the weld. SMA is sometimes specified for repair by the welding code. It takes little time to set up, especially as compared to semiautomatic or automatic welding machines used for TIG, MIG or SAW. Also, it offers excellent control of the weld puddle in all positions. Because of these advantages of SMA for repair welding, many companies prepare and qualify SMA repair welding procedures and welders in anticipation of their need. In this manner, qualified procedures and welders are available whenever the need for weld repair

arises.

Application of Heat Treatments

The heat treatment controls applicable to the original weld also apply to the repair weld. Limits for minimum preheat temperature, maximum interpass temperature, and time and temperature of post weld heat treatment are identical to those of the original welding procedure. Thus, the soundness of the repair weld is not degraded by thermal reactions. However, if the repair volume is very small as compared to the original weld volume, the technical need for post weld heat treatment is lessened. The ASME Boiler and Pressure Vessel Code recognizes instances of small repair volume where post weld heat treatment is not required. In such instances, more stringent control is placed on the repair welding process as an added precaution.

Application of Acceptance Inspection

Repair welds are inspected to the same extent as the original weld. For example, if magnetic particle and radiographic examinations were required for the original weld, both of these inspections are required for the repair weld. This ensures acceptance of the repair weld to the same standard as for acceptance of the original weld.

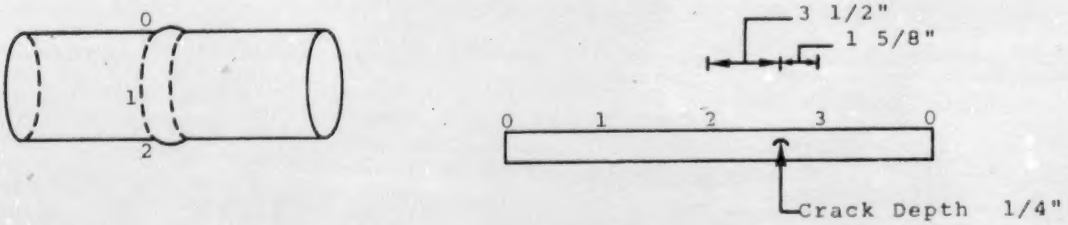
Nonetheless, there is technical basis for an exception to the above. When magnetic particle (MT) or liquid penetrant (PT) examination detects a surface defect, the repair weld is examined only by MT or PT provided the depth of the repair is shallow (within specified limits, e.g., lesser of 3/8" or 10% of weld joint thickness). For such shallow repairs, MT or PT detects the most probable repair weld defects and radiography (or ultrasonics) examination, if performed on the original weld, need not be repeated. With this single exception, repair welds are inspected to

the same extent as the original welds.

Application of Essential Elements of Weld Repair Control

To illustrate the application of the essential elements of a weld repair control program, the sequential events of a weld repair are described below. Responsibilities and duties for these events are delineated by a company's procedures for weld repair.

- Magnetic particle examination of a low alloy steel welded joint in 6" diameter schedule 80 piping reveals no indications and accepts the weld.
- Radiography of the same joint reveals a crack on one of the four exposures taken to cover the entire weld. The inspector prepares a Nonconformance Report and attaches to it the radiographic inspection report and the following sketch:



- The Nonconformance Report is sent to Engineering for disposition. As completed by the inspector, this report identifies (1) the weld joint, (2) type of defect (crack), and (3) location of defect (in the 2-3 zone as identified by the sketch and supported by exposure 2-3)
- The inspector places a Nonconforming Label on the weld joint which identifies the serial number of the Nonconformance Report.
- Engineering recognizes that weld repair is necessary

and enters repair instructions on the Nonconformance Report. The instructions state repair per procedure WR-3 and MT and RT the completed repair per procedures MT-1 and RT-12. These procedures are all qualified. WR-3 requires (1) grinding to remove weld defects, (2) MT of cavity, (3) SMA repair welding, and (4) no post weld heat treatment because the original weld did not require post weld heat treatment.

- Quality engineering reviews the engineer's instructions and concurs with them.
- The Nonconformance Report is sent to the welding department, which assigns the repair work to a grinder and a welder. The grinder locates the zone markings placed on the weld joint by the radiographer and marks the spot in the 2-3 zone indicated by the sketch. In accordance with WR-3, the grinder removes weld metal at this area to a depth of 5/16" and requests an MT inspector to inspect the cavity. MT per MT-1 reveals a linear indication on one side wall of the cavity near the bottom of the cavity. The grinder removes more metal from that sidewall. The MT inspector examines the cavity, finds no indication, and enters the accomplishment of MT of the cavity per MT-1 on the Nonconformance Report. The welder repair welds in accordance with WR-3 and requests MT inspection. The MT inspector examines the repair weld per MT-1 on the Nonconformance Report.
- The Nonconformance Report is sent to the radiography group. The assigned radiographer radiographs the 2-3 zone per RT-12. The radiographic inspector finds the repair meets acceptance standards, enters accomplishment of RT per RT-12 on the Nonconformance

Report, and removes the Nonconforming Label from the weld joint. It is noted that had MT or RT found defects in the repair weld, another Nonconformance Report would have been issued and the entire cycle repeated.

EXERCISES

The following exercises reinforce the information presented in this module:

1. Obtain:
   a. Sample nonconformance report form
   b. Sample reject tag
   c. Sample weld repair control procedure

   from a local company. Following the PROCEDURES listed in this module, discuss the purposes of a weld repair control program and how the nonconforming status of welds is positively identified until such time that weld repair has been accepted.

The remaining exercises may be answered based upon the material presented in this module. An answer key is also provided for these exercises in this section of the module.

2. Read the status of a completed weld as described by each of the following items. For each, assume that all original procedures are qualified and that SMA welding is used for any necessary repair welding. Based on the content of this module, complete the statements following each description.

a. A six inch nozzle weld is made by MIG welding in a pressure vessel and subsequently stress relieved. MT and RT of the weld is required. MT is acceptable but RT finds cracks at 30° and 190° from the reference RT starting point and rejects the weld.

(1) The cracks are open to the surface.
___True ___False

(2) The inspector uses UT to determine depth of each crack. This effort is probably worthwhile. ___Yes ___No Why? (Explain)
_____.

(3) The repair welding procedure required qualification because _____
_____.

(4) Removal of the defects is confirmed by _____ inspection.

(5) Upon completion of the weld repairs, heat treatment is required. ___Yes ___No

(6) Acceptance inspection of the weld repairs consists of _____
_____.

b. Baffles are SMA welded into the internals of a steam generator in close proximity to each other. Each weld is a ½-inch double bevel, fillet reinforced weld, which requires MT of both sides. All welds are acceptable except one, which has a crack on both sides for 80% of the length of the weld.

(1) Weld repair is required. ___Yes ___No.

(2) The best method of removing weld metal is grinding, because _____
_____.

(3) Incremental grinding and MT examination proceeds until _____
_____.

(4) The repair welding procedure requires qualification. ___Yes ___No.

(5) The completed repair weld is accepted by _____ inspection.

c. Liquid penetrant examination of weld deposited stainless steel cladding by SAW reveals five rounded indications in alignment of which three are 1/8", one is 3/16", and one is 1/4"; and two 1/4" rounded indications and five 1/16" rounded indications are randomly disposed. Acceptance standards are as follows:

- Indications 1/16" and smaller are considered irrelevant.
- No cracks.
- Maximum acceptable indication size is 3/16".

(1) The indications which must be removed and repaired are _____ _____.

(2) Assuming that very shallow grinding removes the unacceptable indications such that weld repair is unnecessary, acceptance inspection is not required. ___True ___False.

d. Four inch carbon steel plate is prepared to form a double V butt joint. Prior to initial MIG welding, MT of the weld end faces is required. The MT reveals an unacceptable lamination on one weld end face, which requires SMA weld repair for the depth of the lamination or one inch into the base metal, whichever is less.

(1) When the lamination is ground, who is responsible for confirming defect removal?
___Grinder ___Inspector

(2) The repair welding procedure must be qualified. ___Yes ___No.

(3) Upon completion of repair welding, the MIG welding cannot yet commence because _____ _____.

3. Check your answers to the exercise questions against this Answer Key. Review the text in areas where incorrect answers are noted.

a. (1) False (Because the original MT did not detect cracks.)

(2) Yes (Because of the thickness of the weld joint. Locating defect depth minimizes the amount of weld metal to be removed.)

(3) The repair welding process (SMA) differs from the original welding process (MIG).

(4) Magnetic particle.

(5) Yes (Because post weld heat treatment was required of the original weld.)

(6) Magnetic particle and radiography. (same as the original weld.)

b. (1) Yes (Cracks of this size can safely be assumed to never be acceptable.)

(2) Machining of internals is probably impossible, and thermal gouging has a high risk of gouging and spattering other baffles in close proximity.

(3) There is no longer indication of the crack. (Even if all weld metal must be removed.)

(4) No (Because it is the same as the original procedure.)

(5) Magnetic particle. (Same as for original weld.)

c. (1) The three 1/4 inch rounded indications. (After their removal, remaining indications are acceptable.)

(2) False (Acceptance inspection is always required. In this instance, PT is confirm removal of the unacceptable indications also constitutes acceptance inspection.)

d. (1) Inspector (The act is one of confirmation which is an inspection function.)

(2) Yes (Differs from MIG.)

(3) The repair weld must first be determined to be acceptable by MT examination.

MATERIALS

The following materials are required to support this module:

1. Sample nonconformance report form (optional)
2. Sample reject tag (optional)
3. Sample weld repair control procedure from local company (optional).

PROCEDURES

1. In reference to Exercise #1, visit a local company and obtain the MATERIALS designated for this module.
2. The purposes of a weld repair control program are to:
   a. Positively identify and accurately locate each unacceptable weld defect.
   b. Ensure removal of unacceptable indications prior to commencing repair welding.

c. Ensure use of a qualified repair welding procedure by qualified personnel.

d. Ensure acceptance inspection of the repair weld.

Therefore, from the information you have gathered from a local company along with any discussion with on-the-job personnel discuss whether the company's weld repair control program is consistent with the purpose outlined above.

3. The five essential elements of a weld repair control program are:

   a. Indication of nonconforming status of welds.

   b. Location and removal of defects.

   c. Selection and qualification of repair welding processes/personnel.

   d. Application of heat treatments.

   e. Application of acceptance inspection.

From the information you have gathered, explain if the weld control program you have observed contains the five essential elements listed above.

4. NDE personnel identify location of defects by preparing sketches of the weld joint and relative position of defects in the weld. RT or UT may be used to assist in determining the depth of a defect.

Explain the techniques employed in determining the location and depth of the defects at the company you have visited.

5. Removal of defects may be accomplished by machining, grinding, or thermal gouging. Each method has its advantages and disadvantages.

Describe the method(s) used in preparing the nonconforming weld for repair to the same standard as the original welds at the company you have visited.

DATA TABLE

None.

REFERENCE MATERIALS

ASME, Boiler & Pressure Vessel Code, Section III, American Society of Mechanical Engineers, 3 - New York, N.Y., 1978

AWS, Structural Steel Welding Code, American Welding Society, Miami, Florida, 1976

J.M. Juran, Quality Control Handbook, McGraw-Hill, 1974

ANSI, N45.2, Quality Assurance Program Requirements for Nuclear Power Plants, The American Society of Mechanical Engineers, New York, N.Y., 1971

TEST

1. State four purposes of the weld repair control program.

2. The five essential elements of a weld repair control program are:
   a. Indication of nonconforming status of welds.
   b. Location and removal of defects.
   c. Selection and qualification of repair welding processes/personnel.
   d. Application of heat treatments.
   e. Application of acceptance inspection.

   Briefly discuss how each of these five (5) elements is actually carried out in a weld repair control program.

3. Briefly discuss the circumstances which permit removal of nonconforming status indication from a weld.

4. Describe briefly how radiographic testing or ultrasonic testing may be used in locating weld defects.

5. State one advantage and one disadvantage for each of machining, grinding, and thermal gouging methods of removing weld defects.

6. State two reasons why the SMA welding process is so frequently used for repair welding.

7. Name five items which are included in engineering instructions for removing a weld defect.